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IT for Corruption Suppression

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Abstract

Government agencies and large corporations meet similar problems related to control of agents dealing with outsiders: citizens under audit of the agency or clients of the company. In such interaction there typically exists a possibility of collusion. In order to prevent it, agencies and corporations usually organize hierarchical controlling structures. The present paper considers game-theoretic models of such structures and studies a problem of their optimal organization.

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Keywords: Corruption; hierarchical structures, game-theoretic models.

1. Introduction

For a long time corruption remains one of the main obstacles to economic development of Russia. Recent investigations in the Ministries of Defence and Agriculture and some other government agencies revealed misappropriations of several tens billions rubles.

The country leaders pay great attention to this problem (see the decree of the President of the Russian Federation "About National strategy of counteraction to corruption and the National plan of counteraction to corruption for 2010-2011"), but till the present time there was no essential successes in the struggle against it.

International organizations carry out regular measurements of the corruption level in different countries. According to the report [7] of Transparency International for 2011, Russia is at the 143th place in the 183-point rating showing the perception of corruption. With 2.4 points on a ten-point scale, Russia improved a bit the result for 2010 (2.1 points, the 154th place among 176 countries). The most safe had been recognized Denmark, New Zealand, Singapore (9.3 points). Among leaders there are also Finland, Sweden, Canada, the Netherlands, Australia, Switzerland and Norway.

Several Russian organizations, including fund "Indem" and National anticorruption Committee, are engaged in detailed researches of corruption in Russia. According to their data [2], since 2005 the annual volume of bribes in the business sphere was about $300 bln, which exceeded the Government annual revenue. Businessmen often had to

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pay money to the agencies carrying out control and supervision functions, namely, to fire inspectors, sanitary, and trade inspectors. Corruption at customs and tax inspections was also rather high.

There are different opinions regarding the accuracy of these data. However, both the government of Russia and researchers studying this problem share the opinion that Russia suffers significant economic damage from corruption. In particular, the country's investment attractiveness decreases, and, consequently, the volume of direct investments and the rate of economic growth fall. Corruption particularly depresses the development of small and medium business, for which the struggle against bureaucrats is more difficult than for large companies. The public welfare is redistributed in favour of corrupt bureaucrats. The companies under their control get advantage in the market as they are released from checks, pay less taxes, and get preference under distribution of government orders.

The present paper continues the analysis of the problem of the optimal organization of state inspections. It belongs to the stream of works on economic mechanisms design (see [5]). The present study determines the inspection design such that fair behavior of taxpayers and auditors turns out to be stable to deviations of coalitions. Formal results are obtained for a general problem of the optimal design of a hierarchical controlling structure. In particular, we consider a model of tax inspection. The results are also of interest in context of corporate governance for large companies where employees can collude with clients to the detriment of the company.

Modern ITs make it possible to plan and control from one center the auditing process for millions of economic agents. They permit to organize random auditing with certain probabilities in a multi-level hierarchical controlling agency and thus realize the optimal inspection strategy determined by our model.

There exists a wide literature on models of tax enforcement and corruption in tax inspection (see [1], [3]). While the papers consider exogenous mechanisms for corruption revealing typical for a developed civil society, we examine endogenous tools for its suppression. Another close research direction studies problems of construction of optimal hierarchical structures ([4], [6]). Our model develops this approach by permitting collusion among agents in the hierarchy.

2. The formal model

The model assumes that a benevolent leader comes to power in a country (a region) and aims to organize an efficient inspection that provides compliance of citizens (agents of 0 level) to the law. The set of possible actions is the same for all citizens. Each action is characterized by its cost, and the law determines the correct action depending on the random factor value. This value is a private information of the agent. (For the model of tax inspection, an action is a tax payment, the law determines the tax rate depending on the agent's income). Agents are rational and risk-neutral, so they have an incentive for evasion. In order to prevent it, they are audited with some probability depending on the action. The audit is costly and reveals the random factor value. But auditors (inspectors of the 1st level) are also rational and risk-neutral, so each of them can collude with the audited agent if mutually beneficial collusion is possible.

In order to prevent such outcome, each audit of the first level is reviewed by an inspector of the second level with a certain probability, and so on. The leader has several reliable associates who carry out audits at the top level. A fixed cost of such audit is very high. Each revealed deviation from the correct behavior is penalized according to a given rule. The problem is to find a strategy of inspection organization that provides the correct behavior at the 0 level and prevents corruption in the inspection.

We consider two variants of the model. In the first version, auditing costs and penalty coefficients are fixed for each level. A strategy of inspection is determined by auditing probabilities at all levels, each depending on reports obtained from the lower levels. We consider the concept of stability to deviations of coalitions.

The next variant of the model assumes that the salary of an inspector is a component of a strategy and determines the cost of an audit and the penalty coefficient at each level except for the top one. We show that the optimal strategy is obtained from the first-order conditions for the optimization problem.

2.1. Optimal strategy of multilevel inspection organization

Let $A, (|A| \gg N)$, denote the set of agents at the 0 level. The set T_0 contains possible actions t_0 of each agent $a \in A$. Function $t_0^*(I)$ determines her correct action depending on the value of random factor $I, I \in [I_{\min,} I_{\max}]$, with known function of distribution $F(I)$. Each action of the agent is characterized by cost t on its realization, and values of a random factor I are ordered by increase of the cost of the agent correct action. In case of tax inspection the random factor is an income, t_0 is a tax payment, $t_0^*(I)$ is the tax value according to the effective tax rate.

The inspection operates as follows. An agent at the zero level which has made action t_0 is audited with probability $p_1(t_0)$. The inspector always finds out the true value of I, however, in case of collusion he can report value $t_1 \le t_0^*$. If the inspector reports $t_1 > t_0$ then the agent is punished by the penalty $f_0(t_1 - t_0)$ where $f_0 > 1$ is the penalty coefficient. The cost of one audit at this level is c_1. The audit is under revision, or the second level audit, with probability $p_2(t_0, t_1)$ depending on the action at zero level and the report of the inspector at the first level.

The cost for one revision at this level is c_2. If the inspector of the second level reports $t_2 > t_1$ then punishment is imposed on the agent of zero level in size $f_0(t_2 - t_1)$ and on the agent of the first level in size $f_1(t_2 - t_1)$. And so on: if the lth level audit, realized with probability $p_l(t_{0,\dots,}t_{l-1})$, reveals $t_l > t_{l-1}$, all the agents of subordinate levels connected with the given case are punished by penalties $f_i(t_l - t_{l-1})$. Let k be the number of the top level. If the audit at k th level occurs, it always reveals the true value $t_k = t_0^*(I)$. Thus, strategy P of the inspection organization includes the number of levels k and the probabilities of audits $p_1(t_0), p_2(t_0,t_1),\dots,p_k(t_0,t_1,\dots,t_{k-1})$ as functions of the messages obtained from previous levels. Penalty coefficients f_i and auditing costs c_i at each level are exogenous parameters of the model.

Consider a coalition C_l, including some agents of zero level and all inspectors from level 1 to level l checking their work. Strategy $\vec{T}$ of such coalition is given by functions $t_0(I), t_1(I),\dots,t_l(I)$ that determine the actions of agents and the messages of inspectors if any agent of level 0 from this coalition is audited.

Definition. We name strategy P stable to deviation of coalition C_l if the total expected income of its members reaches its maximum under fair behavior, i.e. at $t_0(I) = t_0^*(I),\dots,t_r(I) = t_0^*(I)$, $r = 1,\dots,l$, under condition of fair behavior of agents at the upper levels $r = 1,\dots,l$.

Proposition 1. Strategy P is stable to deviation of coalition C_l if and only if

$$p_1(t_0)\dots p_s(t_0,t_1,\dots,t_{s-1}) \ge 1/(f_0 + \dots + f_{s-1}) \tag{1}$$

for any values of arguments $t_0,\dots,t_{s-1} \le t_{\max}$, $s \le l+1$.

Definition. Strategy P is stable to coalitional deviations if condition (1) holds for all $l = 1,\dots,k$.

Now determine the optimal strategy of inspection organization that induces fair behavior and minimizes the costs of auditing. Under such behavior, the expected costs are calculated as follows:

$$\int_{I_{\min}}^{I_{\max}} p_1(P,I)(c_1 + p_2(P,I)(c_2 + \dots + p_{k-1}(P,I)(c_{k-1} + p_k(P,I)c_k)\dots)dF(I)$$

where $p_i(P,I) = p_i(t_0^*(I),\dots,t_0^*(I))$

Proposition 2. The optimal strategy stable to coalitional deviations under minimal expected costs meets conditions

$$p_1(t_0) \equiv \hat{p}_1 = \frac{1}{f_0},\; p_s(t_0,t_1,\dots,t_{s-1}) \equiv \hat{p}_s = \frac{\sum_{i=0}^{s-2} f_i}{\sum_{i=0}^{s-1} f_i}$$

for any $t_0,\dots,t_{s-1} \le t_{\max}$, $s = 2,\dots,k$.

2.2. Optimal choice of inspectors' salaries

In the previous model, penalty coefficients for participants and auditing costs were considered as exogenous parameters. In order to apply the model, it is important to understand how they are determined in practice and what is their interrelation. Let us note that an audit reveals not bribing (criminal offense), but only failure to fulfill official duties. Punishment for such infringements is regulated by norms of the administrative legislation, and the maximum punishment is firing without possibility in the future to occupy positions in government organizations. Thus, the punishment relates to the loss of the future incomes in concern with transition to a low-wage job after dismissal. We will find out how the salary of the inspector influences the maximum value of the penalty coefficient.

Let s_l be the salary of an inspector at level l per the time of one audit, and after dismissal he can count on the alternative salary s_{alt}. The exact form of the relation that determines the penalty coefficient depends on behavior of other agents in the given interaction. If fair behavior is typical, then the probability of collision with one more infringer before the end of the previous investigation is close to zero. Then firing is equivalent to the one-shot penalty in size $\tau(s - s_{alt})$ where $\tau = (1-\rho)/\rho$ is the reduction factor, ρ - the discount rate concerning the period of one audit.

Therefore the equation for calculation of f_l becomes $f_l \Delta t = \tau(s - s_{alt})$, where $\Delta t = t_0^*(I_{\max}) - t_0^*(I_{\min})$. The penalty is

$$f_l(s_l) = \frac{\tau(s_l - s_{alt})}{\Delta t} \qquad (2)$$

Let expenses per one audit by a rational inspector of level i include its salary s_i and fixed costs c: $c_i = s_i + c$. The cost of an audit by a top level inspector is exogenously given and equal c_k. Under salaries $s_1,...,s_{k-1}$ the optimal probabilities of auditing are determined according to Proposition 2. Thus the minimal expenses on auditing make

$$C(\bar{s}) = \frac{s_1 + c}{f_0} + \frac{s_2 + c}{f_0 + f_1(s_1)} + ... + \frac{c_k}{f_0 + f_1(s_1) + ... + f_{k-1}(s_{k-1})}$$

where $f_l(s_l)$ are given by (2). Consider a problem of these expenses minimization by salaries:

$C(\bar{s}) \to \min_{\bar{s}}$, under restrictions

$$s_i \geq s_{alt},\ i = 1,...,k-1 \qquad (3)$$

Transform a problem by entering new variables:

$$v = \tau c_k / f_0 \Delta t,\ \gamma = \tau s_{alt} / f_0 \Delta t\ \ d_i = (s_i - s_{alt})/s_{alt}\ ,\ i = 1,...,k-1 \qquad (4)$$

$$u_1 = 1,\ u_i = 1 + \gamma \sum_{j=1}^{i-1} d_j,\ i = 2,...,k \qquad (5)$$

In the new variables the problem (3) becomes:

$$C(\vec{u}) = \frac{\Delta t}{\tau} \sum_{i=1}^{k-1} \left(\frac{u_{i+1} - u_i + \gamma}{u_i} + \frac{v}{u_k} \right) \to \min_{u_2,...,u_k},\ u_1 = 1,\ u_{i+1} \geq u_i,\ i = 1,...,k-1. \qquad (6)$$

Proposition 3. If values u_i^* $i = 2,...,k-1$, determined from the first order conditions:

$$u_{k-1} = \frac{u_k^2}{v},\ u_{i-1} = \frac{u_i^2}{u_{i+1} + \gamma},\ i = 2,...,k-1,$$

meet inequalities (6) then the optimal salaries $s_1^*,...,s_{k-1}^*$ are expressed through these variables according to (4) - (5).

3. Results of optimal strategy calculation for tax inspection of small enterprises in Russia.

Our paper [8] applies these results to a model of taxation of small enterprisers in Russia and determines the optimal strategy of the tax inspection organization. The profit before tax I of such taxpayers takes values from 0 to 1 000 000$ per year with an average I_{avg} = 400 000$. The agent with the profit I should pay the tax $t_0^*(I) = tI$ where the tax rate is 0.2. (According to the data from the Moscow center of development of business, "the average size of the tax from small enterprises of Moscow for 2008 was 80 000$ that made approximately 20 % from pretax profits"). According to the operating tax laws, non-payment or underpayment of the tax implies the penalty at a rate of 40 % from the unpaid sum. However for evasion in large (more than 2 000 000 roubles) and especially large sizes (more than 10 000 000 roubles) the responsibility is determined by the Criminal code of the Russian Federation (article 199): The penalty at a rate of the income condemned for the period till three years or imprisonment for the term up to 6 years with right deprivation to occupy certain positions. Proceeding from this, we set the penalty coefficient for taxpayers: $f_0 \approx 4$. Under the tax rate $t_0 \approx 4$ it corresponds to recovery to the state budget of the hidden income. We assume that the expenses on one audit by the top level inspector are very large since they reflect the shortage of her time: c_k=100 000$. Each inspector makes 5 checks per a month (60 in a year) that corresponds to expert estimations. The alternative salary for the time of one audit is equal s_{alt} = 140$, that is 700$ per month (an average salary in Russia in 2008). We neglect fixed costs (c = 0), the discount rate is =0.0018 for the time of one audit. This corresponds to the annual rate 0.1 and α =570.

For 100 000 taxpayers, the optimal strategy of inspection organization specified by the Proposition 3, requires 559 rational inspectors and 17 fair top-level auditors at k = 4 (for k = 7 - 868 and 11 accordingly). In spite of the considerable number of levels there is no overload of taxpayers by audits: the average number of audits per one taxpayer is 0.56 for the annual period. Under the optimal strategy stable to coalitional deviations, the auditing costs are less than 8% of the net tax revenue.

Our assumption on availability of the optimal number of honest top-level auditors is often questionable in practice. As an alternative consider a model where only one honest top level inspector (the inspection head) is available. In order to prevent collusion at lower levels, the head can revise m audits per year.

The corresponding optimization problem and the first-order conditions for the optimal strategy are similar to discussed in Section 2. Consider the results for the following scenarios of the head's involvement in the revision process: a) full-time involvement (m=60), b) half-time involvement (m=30), c) only one revision per year. We find the minimal cost of corruption suppression for a given number of levels k and compare it with the solution of the similar problem without limitation of the honest revisions' number.

Our results show that for k>6 the optimal strategy under the only one honest inspector provides sufficiently good results from the practical point of view. For k=7 and m=60 the share of the auditing costs in the gross tax revenue does not exceed 5%. Under m=30 this value is a bit larger (5.55%). Even for m=1 the optimal strategy under k=8 permits to organize the inspection with the satisfactory value of 10% loss. The further increase of the level number k does not provide any valuable reduction of the minimal cost and makes the system more complicated.

4. Conclusion.

Our results show that employment of modern mathematical models and IT may substantially reduce the cost of corruption suppression. With regard to tax inspection of small enterprises, the optimal cost does not exceed 4% of the gross tax revenue. Partial involvement of the inspection head in the revision process may compensate the lack of honest inspectors with a moderate increase of the cost by 1.5-2 percentage points.

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